Environmental Impacts of Aqueous Process Alternatives(U)

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Summary of Revisions

Issue Date	Revision	Description
10/31/07	0	Initial Issue

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Aqueous Process Alternatives (U)

1. SUMMARY

This report provides a preliminary assessment of the relative environmental impacts of aqueous process candidates for future deployment compared to the PEIS basis flowsheet, UREX+1a.

The Department of Energy's (DOE) Global Nuclear Energy Partnership (GNEP) is a comprehensive strategy to increase United States and global energy security, reduce the risk of nuclear proliferation, encourage clean energy development around the world, and improve the environment. GNEP recommends that the United States move from a once-through fuel cycle to a new approach that includes recycling of spent nuclear fuel (SNF) without separating the transuranic components of spent nuclear fuel. This capability would employ advanced technologies to increase proliferation resistance, recover and reuse fuel resources, and reduce the amount of wastes requiring permanent geological disposal.

Under the GNEP concept, recycling would accomplish:

- Separation of high purity uranium from the spent fuel that would allow recycle for re-enrichment or for other use or disposition
- Separation and immobilization of long-lived fission products, technetium, and iodine for disposal in a geological repository
- Extraction and temporary storage of short-lived fission products (cesium and strontium) to meet the requirements for disposal
- Separation of transuranic (TRU) elements for fabrication into fuel for an advanced recycling reactor. The advanced recycling reactor would consume the transuranic elements and recover their energy.

DOE has been developing advanced technologies, such as the UREX suite of aqueous-based processes (Table 1) as well as non-aqueous systems, to accomplish these goals. None of these advanced processes are currently employed at production scale, therefore selection of a specific process cannot be finalized at this time; however, all have been demonstrated to be potential candidate technologies which might be deployed in the future. Ongoing technology development, input from DOE's industrial partners, non-proliferation policy, and public comment will all influence the eventual deployment of specific processes. Environmental impact analyses of aqueous systems presented in the PEIS are based on the UREX+1a flowsheet (Figure 1), but other aqueous processes are potential candidates for future deployment. Some alternative processes are shown in Table 1.

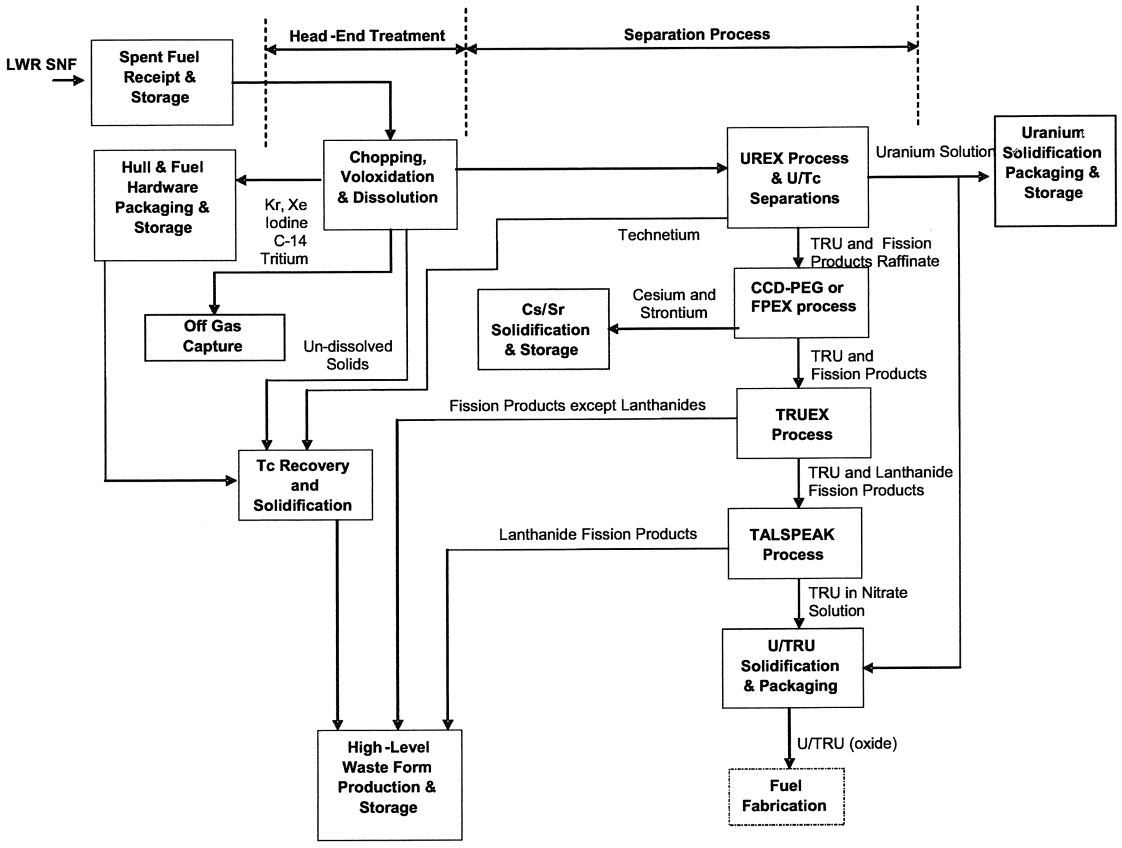


Figure 1 UREX+1a Flowsheet

Table 1 Aqueous Process Alternatives

Process	Prod. #1	Prod. #2	Prod. #3	Prod. #4	Prod. #5	Prod. #6	Prod. #7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	FP		
UREX+1a/b*	U	Tc	Cs/Sr	TRU	All FP		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+ Ln	FP	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	All FP	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	All FP
COEX	U	n/a	n/a	U + Pu	n/a	All FP + minor actinides	n/a

* UREX+1a and UREX+1b differ only in the process used for Cs/Sr separation and have no significant differences in environmental impact.

Per DOE request, WSRC has prepared a preliminary assessment of the relative environmental impacts of this suite of aqueous process alternatives compared to the PEIS basis flowsheet, UREX+1a. Table 2 is a summary of this assessment.

Table 2 Relative Environmental Impacts of Aqueous Process Alternatives

Relative Environmental Impacts of Aqueous Processes									
	Land	Construction Resources	Utility Consumption	Operating Manpower	Waste Volume	Worker Exposure	Impact on Fuel Fab	Transportation	Public Risk
UREX+1	Less	Less	Less	Less	More	Same	More	More	Same
UREX+1a/b	Base	Base	Base	Base	Base	Base	Base	Base	Base
UREX+2	More	More	More	More	More	More	More	More	Same
UREX+3	More	More	More	More	More	More	More	More	Same
UREX+4	More	More	More	More	More	More	More	More	Same
COEX	Less	Less+	Less+	Less	Less+	Less	Less+	Less	Same

Sections 2 through 6 provide a description of each of these process alternatives and the qualitative assessment supporting the environmental impact analysis.

2. UREX+1 PROCESS

Description - Most of the process (from fuel receipt to product and waste storage and disposition) is identical to the PEIS baseline UREX+1a baseline. The UREX+1 variation eliminates the TALSPEAK separation process, therefore the lanthanide fission products (especially Europium) travel with the mixed transuranic stream to the product solidification and packaging operation where a combined product is produced. See Figure 2.

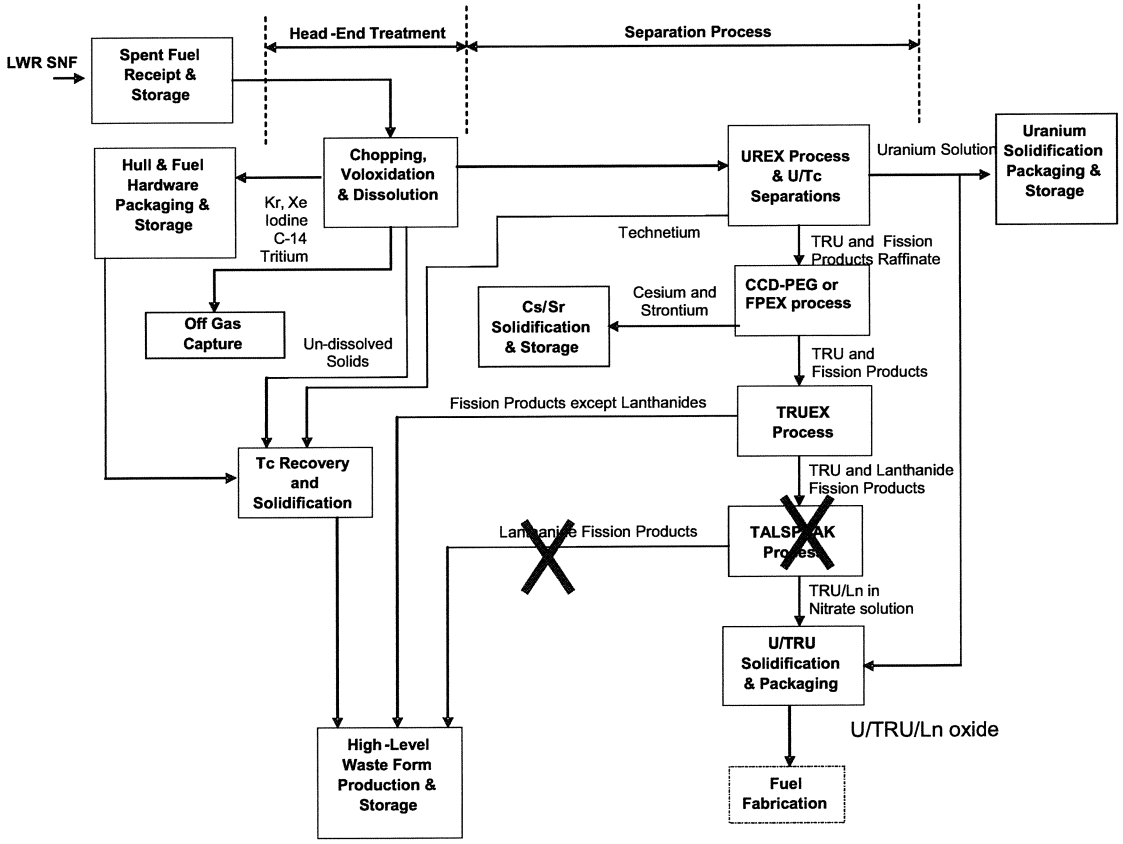


Figure 2 – UREX+1 Process

Compared to the UREX+1a baseline, the following changes result from use of a UREX+1 process.

2.1 Impact

- U/TRU product stream contains lanthanide fission products thereby significantly increasing its radioactivity
- U/TRU product would be less attractive for diversion due to its high radiation field

2.2 Facility Changes

- Extraction facility could be slightly smaller (no TALSPEAK process)
- U/TRU solidification, packaging, and storage facilities would require additional shielding due to the higher radioactivity of the product
- It is likely the U/TRU/Lanthanide product could not be used for reactor fuel. A TALSPEAK-type process would be required at the fuel fabrication facility.

2.3 Environmental Impacts

- At LWR separations facility
  - The extraction facility size would be reduced somewhat (<20%), but would somewhat offset by increased structural requirements at U/TRU solidification, packaging & storage facilities. Construction and operating manpower, utilities, and land usage would be slightly less than the baseline.
  - Any reduction in fission product (HLW) waste resulting from the lanthanide stream being diverted elsewhere would be very small (<5%)
  - Worker exposure is unchanged. The reduced exposure resulting from the smaller extraction operation is offset by increased exposure from the higher rad product handling operations.
- At Fuel Fabrication facility
  - The PEIS baseline assumes that a fast reactor fuel fabrication facility includes an aqueous polishing (dissolving/purification/oxide or metal production) operation, therefore removing lanthanides and handling the HLW will not require addition of major new processing capability, but will result in the need to add HLW vitrification capability. Additional facility construction, manpower, utilities, and emissions would result, but on an overall basis, would be a small addition to the plant (<20%).
  - Aqueous polishing of U/TRU (from a UREX+1a process) would result in low level waste (some of which may be GTCC). Removal of lanthanides from a UREX+1 product stream will result in the creation of a HLW form increasing the overall level of HLW from the

combined LWR separation and FR fuel fabrication activity. The increase has not been quantified and may not be significant.

- Due to the presence of the highly radioactive lanthanide elements, an increase in the dose to workers and those affected by transport of the U/TRU should be expected, although design features would be in place to maintain exposures ALARA.
- Public risk is unlikely to be significantly different than the UREX+1a baseline. Accident scenarios and source terms will be essentially the same throughout most of the separations plant. The presence of lanthanides in the TRU product is unlikely to significantly alter the risk associated with the actinides.

3. UREX+2 PROCESS

Description - Most of the process is identical to the PEIS baseline UREX+1a baseline. The UREX+2 alternative adds an additional separation step (e.g. NPEX) to split plutonium and neptunium from the other actinides (Am and Cm), but eliminates TALSPEAK for lanthanide separation. The lanthanide elements are directed to the Am/Cm stream. (Figure 3) The Pu/Np (with or without U added) product is available for fuel fabrication. The Am/Cm/Lathanide material would be feedstock to a process for preparing the minor actinides for transmutation as targets in a heterogeneous reactor concept. It is unknown if separation of the actinides and lanthanides would be required for target fabrication.

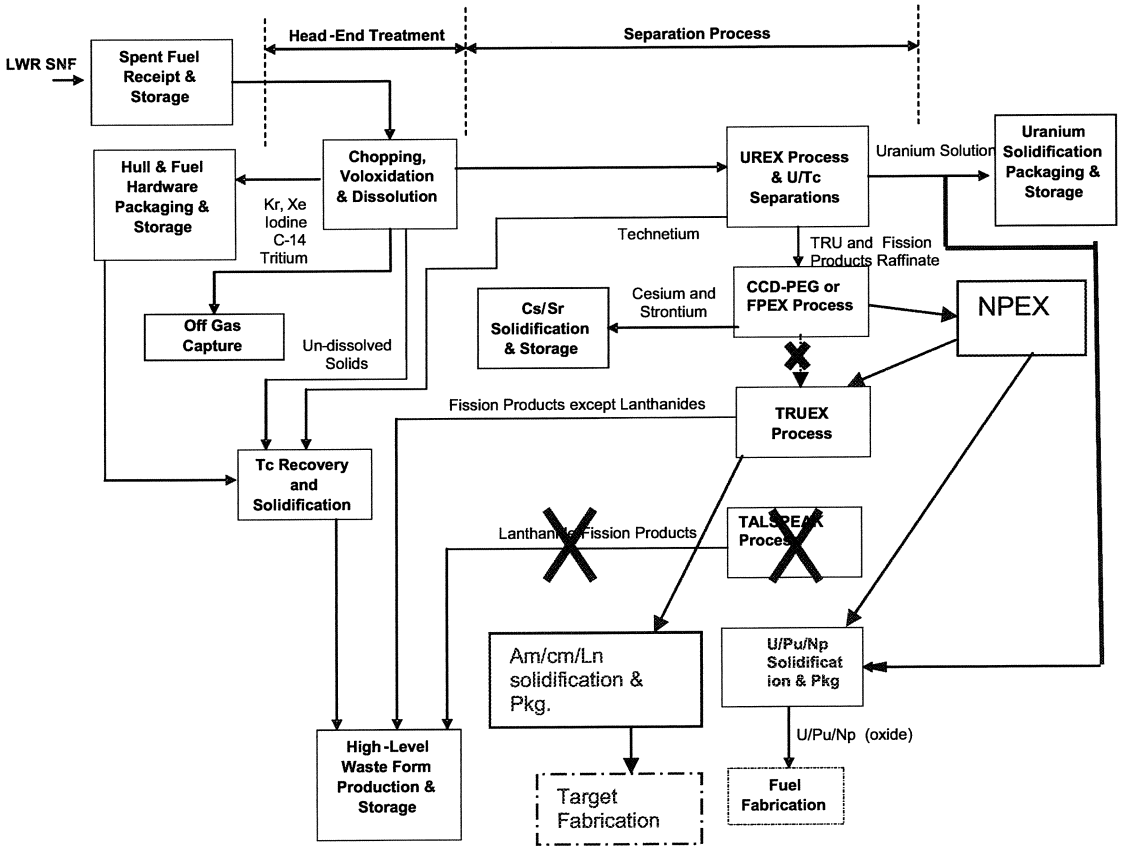


Figure 3 – UREX+2 Process

3.1 Impact

- Pu/Np product stream is less radioactive (than either U/TRU or TRU/Lanthanide) and more closely resembles feedstocks for conventional MOX technology.
- Pu/Np product would be more attractive for diversion
- Am/Cm/Lanthanide product would be extremely radioactive and thermally hot. There is no mature technology to solidify, package, store, transport, or further process this material.

3.2 Facility Changes

- Overall plant size will be greater than UREX+1 due to addition of a process (potentially NPEX) to separate Pu/Np and the higher actinides (Am/Cm), approximately the same size as a plant employing the UREX+1a process. The extra actinide separation of the UREX+2 process is offset by the elimination of the TALSPEAK process in UREX+1a to separate actinides and lanthanides.
- Pu/Np solidification and packaging may be possible in an semi-automated glovebox facility, rather than the hot cell/remote operations needed for products with the higher actinides or lanthanides. Construction labor and materials would be significantly reduced for this operation, but these operations comprise < 10% of the overall LWR separations plant; therefore, any overall reduction would be small.
- The Am/Cm/lanthanide product stream would be small, but solidification, packaging, and storage will be challenging. An expensive hot cell facility will be required, and is expected to more than offset reductions related to glovebox handling of Pu/Np. It is unknown if separation would be required for target use.

3.3 Environmental Impacts

- At LWR separations facility
  - Overall plant size is slightly greater than the UREX+1a benchmark, therefore will result in slightly greater environmental impacts including construction resources and operating manpower, utilities, and land usage.
  - Any reduction in fission product (HLW) waste resulting from the lanthanide stream being diverted elsewhere would be very small (<5%). The fact that an additional product stream is produced is likely to result in a slightly greater overall quantity of waste.
- At Fuel Fabrication facility
  - The PEIS UREX+1a benchmark assumes that a fast reactor fuel fabrication facility includes an aqueous polishing (dissolving/purification/oxide or metal production) operation. This

same facility would be capable of polishing the U/Pu/Np product from a UREX+2 process. While less shielding would be required for Pu/Np than mixed TRU, no major structural or operational differences are expected. Aqueous treatment requirements (if any) for the Am/Cm/Ln target material is unknown. Any treatment (purification/separation) of this highly radioactive material is an engineering challenge requiring complex facilities and processes and will generate additional wastes.

- Fabrication of qualified reactor targets will be a complex process. The combination of fabricating Pu/Np containing fuel and Am/Cm targets is judged to require a larger facility with larger environmental impacts than the homogeneous fuel of the UREX+1a/b approach.

- Due to the presence of the highly radioactive lanthanide elements, an increase in the dose to workers and those affected by transport of the U/TRU should be expected, although design features would be in place to maintain exposures ALARA.
- Public risk is unlikely to be significantly different than the UREX+1a baseline. Accident scenarios and source terms will be essentially the same throughout most of the separations plant. The presence of lanthanides in the TRU product is unlikely to significantly alter the risk associated with the actinides.

4. UREX+3 PROCESS

Description - Most of the process is identical to the PEIS baseline UREX+1a baseline except for the addition of NPEX to split Pu and Np from Am and Cm. The UREX+3 alternative includes the additional separation step (e.g. NPEX) to split plutonium and neptunium from the other actinides (Am and Cm), and, compared to UREX+2, restores a TALSPEAK process for lanthanide separation. The lanthanide elements are directed to the fission product waste stream (HLW). (Figure 4) The Pu/Np (with or without U added) product is available for fuel fabrication. The Am/Cm material would be feedstock to a process for preparing targets for a heterogeneous reactor concept.

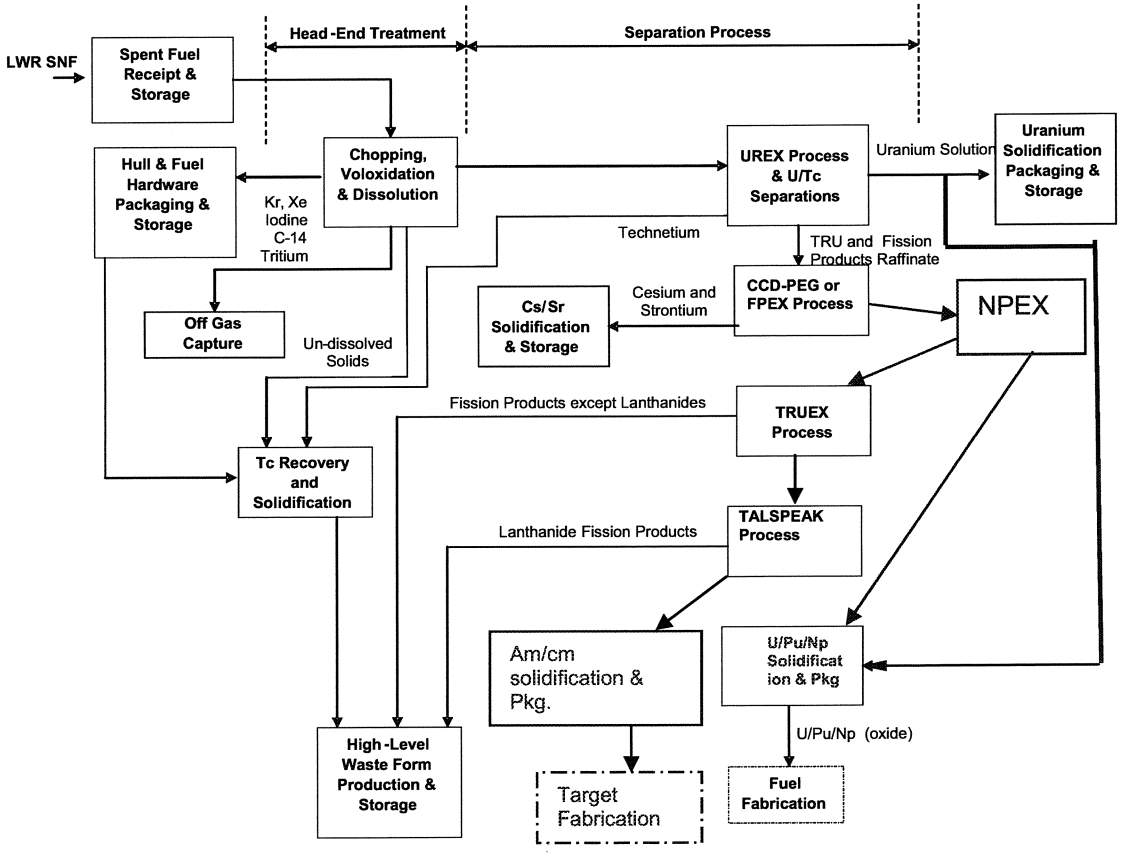


Figure 4 – UREX+3 Process

4.1 Impact

- Pu/Np product stream is less radioactive (than either U/TRU or TRU/Lanthanide) and more closely resembles feedstocks for conventional MOX technology.
- Pu/Np product would be more attractive for diversion
- Am/Cm product will be highly radioactive and thermally hot. There is no mature technology to solidify, package, store, transport, or further process this material.
- All fission products combined in a single waste form is the same as the UREX+1a/b benchmark

4.2 Facility Changes

- Overall plant size may be slightly larger than the UREX+1a/b benchmark. due to
  - addition of a process (potentially NPEX) to separate Pu/Np and the higher actinides (Am/Cm).
  - Pu/Np solidification and packaging may be possible in an semi-automated glovebox facility, rather than the hot cell/remote operations needed for products with the higher actinides or lanthanides.
  - The Am/Cm product stream would be small, but solidification, packaging, and storage will be challenging. An expensive hot cell facility will be required.

4.3 Environmental Impacts

- At LWR separations facility
  - Overall plant size is slightly greater than the UREX+1a/b benchmark, therefore will result in slightly greater environmental impacts including construction resources and operating manpower, utilities, and land usage.
  - The fact that an additional product stream is produced (compared to benchmark) is likely to result in a slightly greater overall quantity of waste.
- At Fuel Fabrication facility
  - The PEIS UREX+1a benchmark assumes that a fast reactor fuel fabrication facility includes an aqueous polishing (dissolving/purification/oxide or metal production) operation. This same facility would be capable of polishing the U/Pu/Np product from a UREX+3 process. While less shielding would be required for Pu/Np than mixed TRU, no major structural or operational differences are expected. Aqueous treatment requirements (if any) for the Am/Cm target material is unknown. Any treatment (purification/separation) of this highly radioactive material is an

engineering challenge requiring complex facilities and processes and will generate additional wastes.

- Fabrication of qualified reactor targets will be a complex process. The combination of fabricating Pu/Np containing fuel and Am/Cm targets is judged to require a larger facility with larger environmental impacts than the homogeneous fuel of the UREX+1a/b approach.

- Due to the separation on Am/Cm into a separate product stream requiring more facilities and equipment and resulting in more containers to be stored and transported, an increase in the dose to workers and those affected by transport of the products should be expected, although design features would be in place to maintain exposures ALARA.
- Public risk is unlikely to be significantly different than the UREX+1a/b benchmark. Accident scenarios and source terms will be essentially the same throughout most of the separations plant. The separation of the transuranics into two streams is unlikely to significantly alter the risk associated with these materials.

5. UREX+4 PROCESS

Description - Most of the process is identical to the PEIS baseline UREX+1a baseline except for the addition of NPEX to split Pu and Np from Am and Cm. An additional separation step will be required to separate Am and Cm (technology to perform this separation is available but very immature for application at commercial scale). All fission products, including lanthanide elements, are directed to a single waste stream. The lanthanide elements are directed to the fission product waste stream (HLW). (Figure 3) The Pu/Np (with or without U added) product is available for fuel fabrication. Americium and potentially curium could be feedstock to a process for preparing targets for a heterogeneous reactor concept.

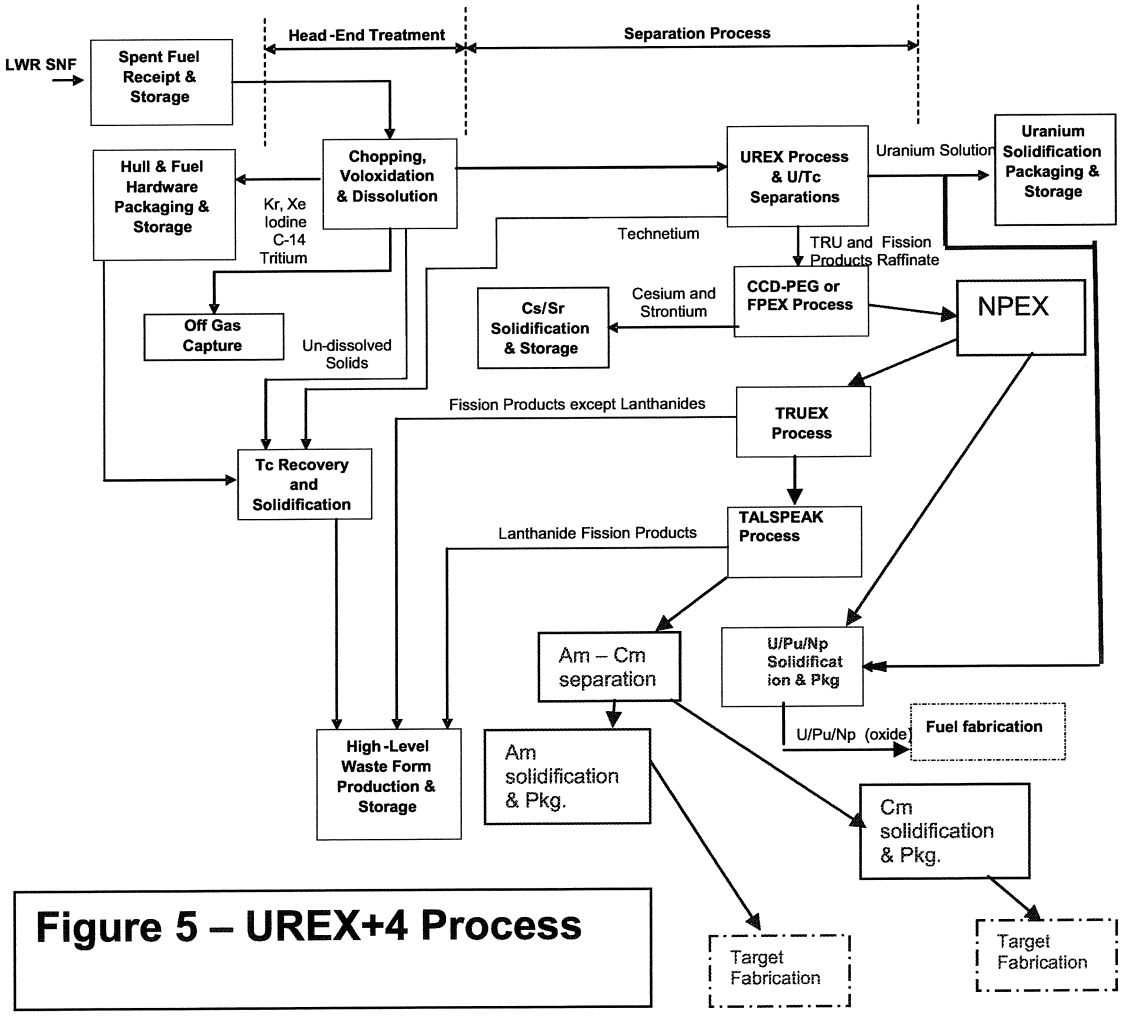


Figure 5 – UREX+4 Process

5.1 Impact

- Pu/Np product stream is less radioactive (than either U/TRU or TRU/Lanthanide) and more closely resembles feedstocks for conventional MOX technology.
- Pu/Np product would be more attractive for diversion
- Am product will be highly radioactive and thermally hot. There is no mature technology to solidify, package, store, transport, or further process this material.
- Cm product has never been handled except in lab quantities. Extreme engineering challenge to solidify, package, store, and use this material
- All fission products combined in a single waste form is the same as the UREX+1a/b benchmark

5.2 Facility Changes

- Overall plant size will be larger than the UREX+1a/b benchmark. due to
  - addition of a process (potentially NPEX) to separate Pu/Np and the higher actinides (Am/Cm).
  - Pu/Np solidification and packaging may be possible in an semi-automated glovebox facility, rather than the hot cell/remote operations needed for products with the higher actinides or lanthanides.
  - The Am and Cm product streams would be small, but solidification, packaging, and storage will be challenging. Two separate lines may be required to avoid cross-contamination. Expensive hot cell facilities will be required.

5.3 Environmental Impacts

- At LWR separations facility
  - Overall plant size is slightly greater than the UREX+1a/b benchmark, therefore will result in slightly greater environmental impacts including construction resources and operating manpower, utilities, and land usage.
  - The fact that two additional product streams are produced (compared to benchmark) is likely to result in a somewhat greater overall quantity of waste.
- At Fuel Fabrication facility
  - The PEIS UREX+1a benchmark assumes that a fast reactor fuel fabrication facility includes an aqueous polishing (dissolving/purification/oxide or metal production) operation. This same facility would be capable of polishing the U/Pu/Np product from a UREX+3 process. While less shielding would be required for Pu/Np than mixed TRU, no major structural or operational differences are expected. Aqueous treatment requirements (if any) for the Am/ or Cm material is unknown. Any treatment

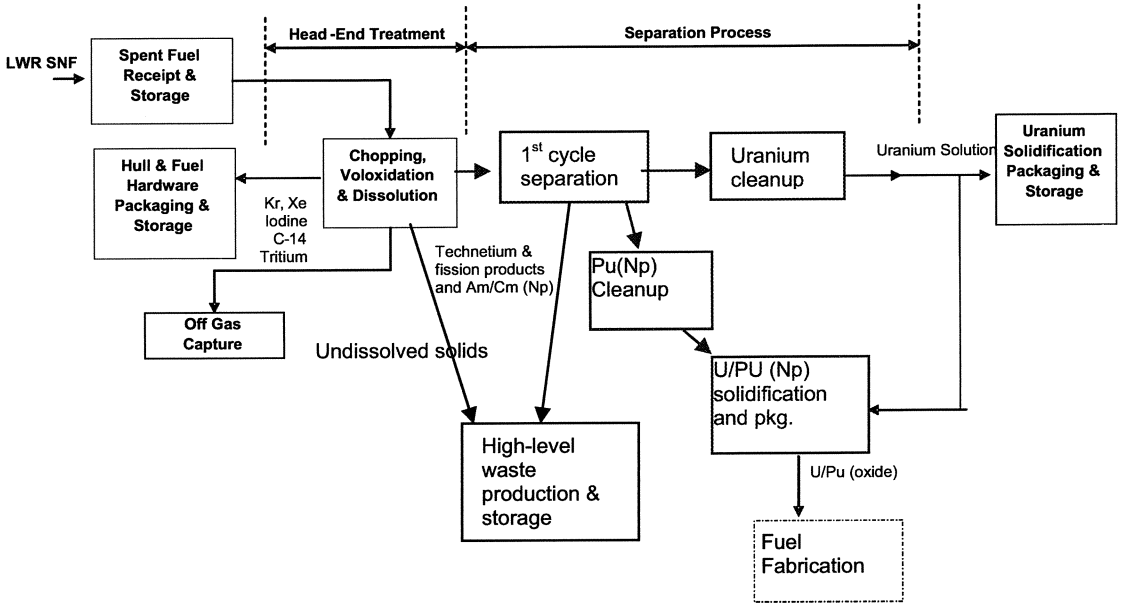
(purification/separation) of this highly radioactive material is an engineering challenge requiring complex facilities and processes and will generate additional wastes.

- Fabrication of qualified reactor targets will be a complex process. The combination of fabricating Pu/Np containing fuel and Am and Cm targets is judged to require a larger facility with larger environmental impacts than the homogeneous fuel of the UREX+1a/b approach.

- Due to the separation on Am and Cm from the major transuranics as well as from each other into separate product streams requiring more facilities and equipment and resulting in more containers to be stored and transported, an increase in the dose to workers and those affected by transport of the products should be expected, although design features would be in place to maintain exposures ALARA.
- Public risk is unlikely to be significantly different than the UREX+1a/b benchmark. Accident scenarios and source terms will be essentially the same throughout most of the separations plant. The separation of the transuranics into two streams is unlikely to significantly alter the risk associated with these materials.

6. COEX PROCESS

Description - The front end of the plant (fuel receipt, storage, chopping, voloxidation, dissolving, hull disposal, etc) is the same as a UREX+1a plant. The separation processes and product and waste management are equivalent to the world's newest commercial LWR separation facility at Rokassho, Japan. The product is a blended U/Pu oxide; Np may be added to the product or directed to waste. Pu is not recovered as a pure product



6.1 Impact

- The U/Pu product stream is the feedstock for conventional MOX technology. Fuel fabrication technology using this product is known. Addition of Np introduces more complications
- U/Pu product would be more attractive for diversion
- Process technology is mature. Reduces licensing and project risk.
- Waste forms and processes are mature

- Significantly reduces process and waste operations reducing construction and operating costs.
- This product may not be suitable for fabricating fast reactor fuel. May only be usable in a thermal reactor recycle strategy

6.2 Facility Changes

- Overall plant size will be significantly smaller than the UREX+1a/b benchmark due to:
  - Fewer extraction processes and support systems
  - Fewer product and waste solidification, packaging and storage operations

6.3 Environmental Impacts

- At LWR separations facility
  - Overall plant size is significantly reduced from the UREX+1a/b benchmark, therefore will result in significantly reduced environmental impacts including construction resources and operating manpower, utilities, and land usage.
- At Fuel Fabrication facility
  - The PEIS UREX+1a benchmark assumes that the reactor fuel fabrication facility includes an aqueous polishing (dissolving/purification/oxide or metal production) operation. This same facility would be capable of polishing the U/Pu or U/Pu/Np product from a COEX process but less shielding would be required than for mixed TRU. Operations generally would be conducted in gloveboxes rather than hot cells. The facility would be significantly smaller and less costly.
  - GNEP programs may require fabrication of fuels at significantly higher Pu loading than conventional MOX fuel (>10% Pu). This will impose additional constraints on the fuel fab plant but would not result in major physical changes.
- Dose to workers and those affected by transport of the products and wastes should be lower than UREX options since fewer containers are produced and handled. Regardless, design features would be in place to maintain exposures ALARA.
- Public risk is unlikely to be significantly different than the UREX+1a/b benchmark. Accident scenarios and source terms will be essentially the same as other cases.